"NONENAL POTENTIAL" & BEER FLAVOR STABILITY

Cardboard vs. Sherry Notes

Meilgaard: "cardboard", "papery", "bready" flavors diminish in intensity over time in forced aging of packaged product.

"Cardboard Flavor" term first coined by **Burger** *et al* in 1954!

"Oxidized" flavors either cardboard- like (e.g. nonenal) or sweet, sherry, caramelized notes.. packaged beer D.O. levels affects latter, not former flavors. former correlated with nonenal potential instead... beer with zero D.O. will therefore still develop cardboard flavors.

Beer stored with high oxygen develops a sweet, caramelized character, not cardboard, suggesting trans-2-nonenal is not formed by free radical reactions in beer?

O^{18} added to headspace does not end up in carbonyl fraction of aged beer .. indicates cardboard flavor not due to *de novo* lipid oxidation in the bottle (i.e. stale flavors do not solely arise from oxidation in the package).

When the $[SO_2]$ is low in beer, large quantities of trans-2-nonenal are formed despite low n.p.

NP of **colored malts** is much, much higher (5-50x) than **pale malts**, with the T2N:protein adducts carrying through to wort to a far greater extent!!!! Adducts degraded in mashing with pale malts.

EBC: "contrary to most earlier findings generally indicating higher thermal loads on worts increase nonenal potential and are detrimental to beer flavor stability, the authors studies found that higher nonenal potentials in cold wort were observed with: a) **shorter kettle boils, b) decreased evaporation, c) lower whirlpool temps or d) lowering wort pH**.

KIRIN: directionally, can reduce wort nonenal potential by lower pH's during wort boiling and clarification. Increase NP by reducing thermal load during wort boiling & clarification (e.g. lower temps or times). In other words, longer boil times or higher temps lower NP.

Process Survey

Interbrew proposes that trans-2-nonenal is synthesized by lipid oxidation before fermentation, but protected from yeast reduction by binding to amino acids/proteins during mashing and boiling ... remaining bound until released at lower pH's in package beer.

Acidified sparge water containing 600ppm lactate and 1000 ppm calcium chloride lowers n.p.

Fermentation temperature, or wort dissolved oxygen level, has little impact on beer nonenal potential.

Wackerbauer: **Nonenal Potential** (NP) of malt does not correlate with subsequent beer flavor stability.

Boiling time and evaporation rate has little effect on nonenal potential.

Treating last runnings with 1000 ppm activated carbon for 2' lowers n.p.

Flavor Stability

Assay Principles

Nonenal potential of wort correlates with staling potential or subsequent beer, therefore flavor stability involves a wort preparation component not just packaging issues...lowering oxygen pick-up during mashing, especially during protein rest, lowers nonenal potential of beer.

Deuterated nonenal added to wort is reduced by yeast to nonenal - but does not end up in carbonyl fraction of aged beer indicating: i) oxidation of the alcohol to aldehyde does not occur in the bottle and ii) no protection by adduct with SO_2 during fermentation.

A non-oxidative degradation product of trans-2-nonenal synthesized before fermentation is proposed to be the major precursor of the cardboard flavor in aged beer.

Oxidation of linoleic acid only occurs before fermentation, leading to trans-2-nonenal, which is protected from yeast reduction by linkage to amines. Only released later in package beer.

"Nonenal Potential" measured by adjusting 10 ml of wort and 40 ml buffer to pH 4.0 (0.1 M acetate) ... purge with argon to reduce D.O. ...heating in closed vessel for 2 hrs at 100^0C ... cool O/N ... assay for trans-2-nonenal. **Wackerbauer** *et al* recommend pH of 1.0 and 90 minutes as optimal.

"NP" = nonenal formed after 2 hr/100^0 C/anaerobic/pH 4.0 = bound carbonyl (amino acids &/or protein) + intermediate precursors (i.e. not de novo nonenal) converted to free.

O^{18} added to headspace of packaged beer ends up in oxidation products of polyphenols, IAAs and sulfites, but not carbonyl compounds. Demonstrates cardboard flavors do not arise from *de novo* lipid oxidation, but from wort preparation.

Process Survey

Last runnings are very high in nonenal potential compared to first wort..spent grains high in n.p. and extractable in hot water...prolonged sparging aggravates.

Adding of amino acids to wort should delay carbonyl release and inhibit oxidation flavors in beer

Emphasized protecting reducing power potential of wort & beer to limit formation of carbonyl precursors by oxidation reactions - even in mashing!

Mashing with coarser grade grind lowers NP...finer grade increases NP.

Use of **LP-malt** with outer layers removed....reduces trans-2-nonenal potential by 50%.

Schiff base adduct structure of carbonyl: amino acid stable at wort pH's .. degrades at lower pH's of beer to release free carbonyls.

[Trub], [linoleic acid], [D.O.], increase wort NP during clarification (-)

Assumes the non-oxidative mechanism applies to other carbonyls as well (e.g. HMF, furfural, etc...).

Prevent/limit Schiff base pairing in wort by adding 50 ppm SO_2 after lautering (or early kettle)... SO_2 inhibits bond formation and oxidation of lipids to carbonyl.

Lowering sparge water temp from 80 to 70^0C lowers NP. Acidifying sparge water, wort production under CO_2 lowers NP, as does efficient removal of hot trub.

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